THE APPLICATION OF DIGITAL GENETIC ALGORITHM IN LACQUER DECORATION DESIGN

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ABSTRACT

The purpose of this study is to explore the integration of MATLAB software and iterative algorithm techniques to enhance the design of decoration mechanisms in traditional lacquer art. MATLAB's computational power is harnessed to simulate and optimize the decorative process, particularly focusing on the lacquer crackle effect technique. This study is a qualitative research and quantitative research method, after experimentation, 100 sample techniques were collected. Taking the lacquer crackle effect technique decoration as an example, the optimal target parameter configuration is achieved. The study aims to present an innovative design method that merges traditional lacquer techniques with modern computational tools, highlighting the rich cultural heritage behind lacquer art while improving the efficiency and creativity of the design process.

The results of the research found that:

1) the genetic algorithm technique could streamline the design process, enhance the quality of the decorative effects, and preserve the cultural heritage of lacquer art in a digital form.

2) Genetic algorithms evolve the most efficient configurations through repeated iterations, resulting in improved product design efficiency and enhanced overall aesthetics of the pattern.

3) The research results make an important contribution to the field of digital design and the preservation of traditional lacquer art, while also providing a new path for the future application of digital technology in the study of traditional art forms.

Keywords: genetic algorithm; lacquer technology; lacquer products; MATLAB.

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1. INTRODUCTION

The use of lacquer is a traditional oriental art. It has become an ancient art with national characteristics through inheritance and development. The history of Chinese arts and crafts has a brilliant historical achievement. Lacquer art embodies artisans' wisdom and is a traditional Chinese cultural treasure. From the Neolithic Age to the Han Dynasty, the lacquer craft has significantly been developed and widely used. As people's demand rises, the design of lacquer ware products develops from handmade to factory production. Lacquer ware decoration is rich in motivational effects, and its use as decorative patterns is widely used in textile, clothing, advertising, and packaging design. The unique decorative art image contains the special aesthetic meaning of oriental culture. Exploring the fusion of craftsmanship and digital technology to create unique lacquer works that break through the limitations of traditional handmade production (Lee, 2021).

The rapid development of digital technology has created conditions for global life. It is not only applicable to industrial production but also helps to preserve our traditional culture. Genetic algorithm is a search algorithm based on natural genetics that uses the superior and inferior choices in the string structure. By combining structured information, a search algorithm is formed with the ability of human search innovation (Goldberg, 1989). Genetic algorithms mimic the process of biological evolution and heredity, starting from a set of viable initial populations and gradually approaching the optimal solution to the problem under study through genetic operations such as selection, crossover, and mutation (Liu, 2008). In product design, genetic algorithm is an integral part of genetic coding and plays a vital role. In this field, the more applied coding methods are tree structure, accurate number, and binary coding. These coding methods are perfect for achieving the innovative requirements of the designer (Hong, 2003). Using genetic algorithms to design novel building floor plans also demonstrates that evolutionary computation can enable intelligence to acquire the ability to learn and generate new buildings (Duan, 2019). The computer is a powerful algorithmic function to select the optimal design scheme saves the designers a lot of modification time.

Presently, preserving non-heritage culture usually requires more financial and human resources. Even more time is spent, it cannot achieve the same effect as the physical object. Genetic algorithms can convert the information of non-heritage products into binary code, which is easy to archive. It is easy for computers to read and identify (Zhu, 2019). Lacquerware is China's intangible cultural heritage, and digital technology for traditional lacquer art handmade product belts opens up a new space for development. digital tools allow artisans to explore more design possibilities, providing new methods for preserving and transmitting cultural heritage to younger generations. By digitizing traditional art-making processes, including patterns and structures, these technologies help protect cultural heritage while also enhancing artisans' creativity, enabling them to expand the boundaries of traditional design. (Wang, 2020). Solve the relationship between digital technology and traditional arts and crafts and better maintain the unique culture of traditional lacquer art.

2. OBJECTIVES

1) To use MATLAB software to design a modern lacquer art to achieve the optimal configuration of target parameters in an infinite step of evolution-hybridisation-selection. This is to provide the optimal design solutions for lacquer art pattern innovation.

2) Generate lacquer pattern art by combining genetic algorithm with the creativity of lacquer artists to obtain the principles of experimental lacquer technique.

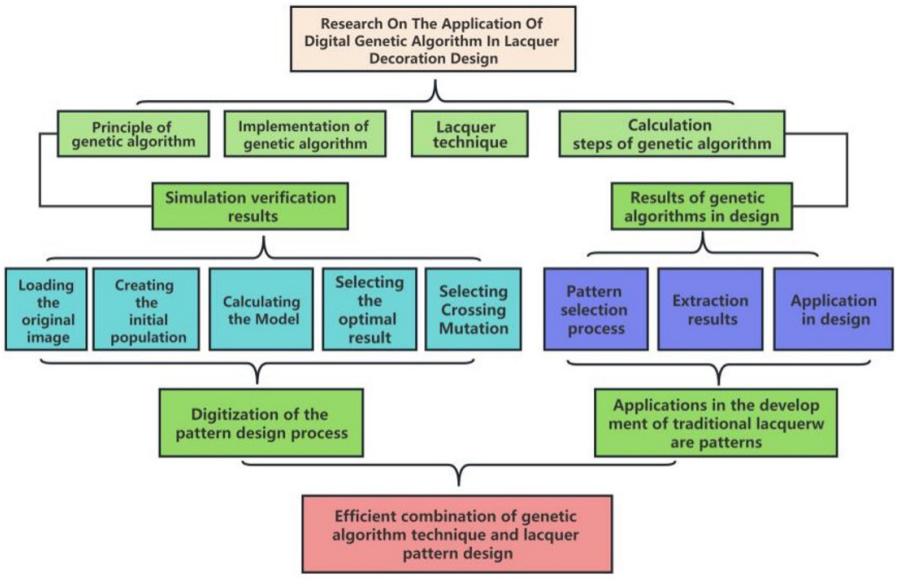
3) Enhance the innovative design method of traditional lacquer art techniques, improve the public's awareness of traditional lacquer art, and highlight the culture of lacquer art.

3. CONCEPTUAL FRAMEWORK

The scope of this study is the application of computerized genetic algorithm technology in traditional lacquer pattern design. The genetic algorithm's theoretical basis includes the genetic algorithm's principle, the Fit function, and the implementation of the genetic algorithm. The innovative design solution integrates the iterative calculation of genetic algorithms into the design process to improve the degree of automation and product design efficiency. The computational steps include image selection, model construction, genetic operators (crossover and mutation), and logical relationships generated by the algorithm design. The design samples for simulation validation were collected first-hand from lacquer traders, and the program was designed to conform to the lacquer pattern algorithm according to the principle of classification management. The experimental data of the algorithms were statistically analyzed to infer the impact of the algorithm design on the generation of innovative lacquerware patterns and to highlight the advantages of using genetic algorithms (Figure 1).

Figure 1

Conceptual Framework



4. RESEARCH METHODOLOGY

This study surveys lacquer techniques and pieces in Jiangxi, China, over the period from May 2021 to August 2022. It involves 31 participants from Nanchang City, Jiangxi Province, including artisans, inheritors, producers, experts, and designers. The interviewees were selected using purposive sampling. A qualitative research method was primarily applied, supplemented by quantitative methods during the experimental phase. The research process is as follows:

1. Collecting information: The analysis of digitalization in the description of traditional skills innovation through secondary sources to obtain literature research methods to understand the design principles and characteristics of genetic algorithms.

2. Experimental analysis: The data collected during the analysis of genetic algorithms and their application in the design of lacquer patterns were analyzed using statistical methods. The algorithm's efficiency was measured through experiments, simulations, and models, with the experimental data subjected to statistical analysis. Numerical data were used to deduce the logical relationships within the algorithm design, enabling the generation of different combinations of the three types of patterns. Finally, quantitative methods were applied to assess the effectiveness of the innovative lacquer pattern design generation.

3. Field Investigation: In Nanchang City, artisans, inheritors, producers, experts, and lacquer product designers involved in lacquer technology were interviewed to obtain first-hand information, all actively engaged in lacquer art and production. The aim was to ensure that participants had direct experience or expertise in lacquer techniques. This method was chosen to target specific individuals who possess valuable insights into both traditional and innovative lacquer techniques, thereby ensuring the collection of relevant and rich data for the study. The goal was to gather insights from participants with distinct roles and knowledge related to the art of lacquer.

4. Information Checked: Feedback on the lacquerware products was collected, and the raw data were analyzed to refine the process of final product design. This analysis focused on the number of iterations needed to achieve the optimal solution and the quality of the resulting designs. Ultimately, a quantitative scoring method will be employed to assess the aesthetics of the lacquerware pattern generation, while a regression model will be utilized to examine the specific parameters of the genetic algorithm.

5. EXPERIMENTS AND RESULTS

5.1 Principle of Genetic Algorithm

Genetic algorithm is a computational model of the biological evolutionary process that simulates the Darwinian biological evolutionary theory of natural selection and the mechanism of genetics, and it is a method of searching for optimal solutions by simulating the natural evolutionary process (Holland, 1975). The idea behind the gene concept in genetic algorithms is to mimic the process of natural selection and evolution, where genes represent specific traits, chromosomes represent individuals, and the Fit function evaluates an individual's adap-

tation to its environment. Several genes form a chromosome (individual). After repeated iterations (generational inheritance), the final optimization results were obtained.

1) The 0th generation population P is initialized with a set of potential solutions (individuals).

2) For the P iteration of the second-generation population, steps ①-⑤ are performed until the stopping criterion is satisfied.

① The Model Fit of each individual in population P is calculated.

② From population P, the individuals with the best Model Fit (highest Fit) are selected and added to the next-generation population, denoted as Pi+1.

③ Two parents are selected from population P based on their Model Fit.

④ After selecting the parents, a genetic operation (crossover or mutation) is performed on them. The generated offspring are then added to the next generation population Pi+1.

⑤ If the scale (size) of Pi+1 equals the size of P, the algorithm proceeds to the next iteration (i←i+1) and goes back to ② to repeat the process with the next generation.

5.2 Implementation of Genetic Algorithm

Appropriate population size can improve the performance of the algorithm. If the population is a significant role, it will complicate the set problem (Back, 1997). In the sample set reduction problem, this algorithm does not have too many restrictions on the size of the population number, but also will carry out different tests on the number of different populations, in order to roughly obtain a better range of population number.

The Fit fi (i = 1, 2, 3,..., M) of each individual in the population is calculated. And M is the population size. The probability of each individual being inherited into the next generation population is calculated:

$$p_i = \frac{f_i}{\sum_{i=1}^{M} f_i} \qquad (1)$$

Calculate the probability distribution of each individual:

$$q_i = \sum_{j=1}^{i} p(x_j) \qquad (2)$$

5.3 Lacquer Technique

Lacquer techniques can be roughly divided into 8 categories: repainting, changing painting, depicting, grinding painting, paint inlay, paint piling, filling, and engraving (Figure 2). They are constantly evolving in the actual creation, each of which has a variety of evolving techniques, extending more than 100 changes.

Figure 2

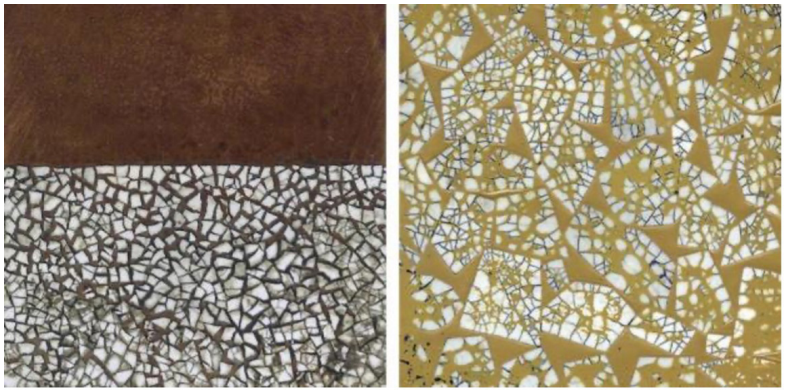
Eight techniques of lacquer art

Source: Author, 2022

According to the analysis of classification of patterns of lacquer art, based on the different levels, the pattern can be divided into 3 categories. The first category is the pattern of plain types, such as repainting, changing painting and depicting. The second category is downward. The recessed decoration means subtraction, including filling and engraving. The third type is superimposed upwards, which has the protruding effect, such as paint inlay, paint piling (Figure 3).

Figure 3

Inlaying eggshell into lacquer painting



Source: Author, 2022

5.4 Calculation Steps of Genetic Algorithm

By using genetic algorithm, based on software MATLAB, this program takes inlaying eggshell into lacquer painting as an example. Aiming at the reduction of sample, this algorithm does not have too many restrictions

on the size and number of the population. Also, it will conduct different tests on different population numbers, so as to obtain a better population number within a better range. The specific design process is shown below:

Step 1: Loading the original image: Through 100 eggshell inlaid images approaching the original image loaded, the image is expressed in the form of a matrix. This study can identify the 100 eggshell inlaid substances as the "gene" of the individual.

Step 2: Creating the initial population: The population is represented by the 7200×total_amount matrix, in binary form (7200=8×(2×3+3)×100, the 8-bit binary number represents the direct number from 0 to 255, and the "gene" of each individual is the spot color and random of 100 triangles.

Step 3: Calculating the Model: The Fit is a measure of adeptness to its living environment of species. Species with a higher degree of adaptation to their living environment will have more reproductive opportunities, while species with a lower degree of adaptation to their living environment will have relatively fewer reproductive opportunities, or even gradually become extinct.

Step 4: Selecting the optimal result: This procedure gives special care to the genes of the 2 generations with the highest Fit in each generation cycle, which are directly inherited into the next generation cycle without selection, crossover or mutation.

Step 5: Selecting: The operation of selecting individuals from a population with a certain probability. In general, selection is a Model Fit. The selection probability of each population is calculated, and the cumulative probability is further obtained, compared with a random number generated in the interval [0,1]. If the random number is less than or equal to the cumulative probability of the individual and greater than the cumulative probability of the individual 1, the individual is selected to enter the offspring population.

Step 6: Crossing: Gene crossing, or recombination, is the process by which parts of two fathers are replaced to create a new individual. The specific operation is to randomly generate a mask word to determine how the offspring individual to obtain genes from the parent individual. The length of the mask word must be the same as the length of the individual gene string, and all of them are generated by 0, 1. It can prevent convergence to local extreme points when converging, and has better recombination ability than classical crossover.

Step 7: Mutation: The progeny individuals produced after gene crossing may change their variables with a small probability or step size, which is called mutation.

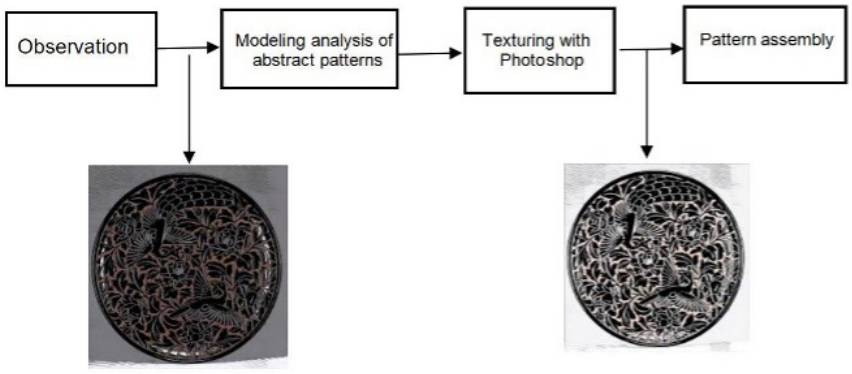
If the generated results cannot meet the requirements of the designer, the pattern can be modified by copying, deleting and moving the individual patterns in the visualization environment.

5.5 Simulation Verification Results

After the pattern generated by the above genetic algorithm operation, the designer can further refine the satisfactory pattern with software Photoshop, and then save them into the pattern library. After standardization of each pattern, the study introduces how to generate paint pattern. Here is a combination of automatic assembly and manual modification to generate paint pattern (Figure 4).

Figure 4

The process of pattern design

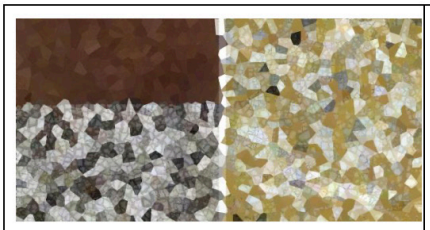
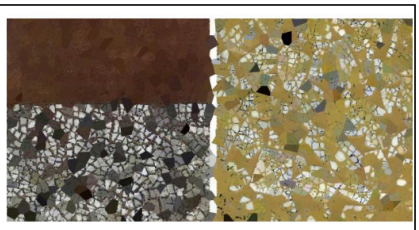


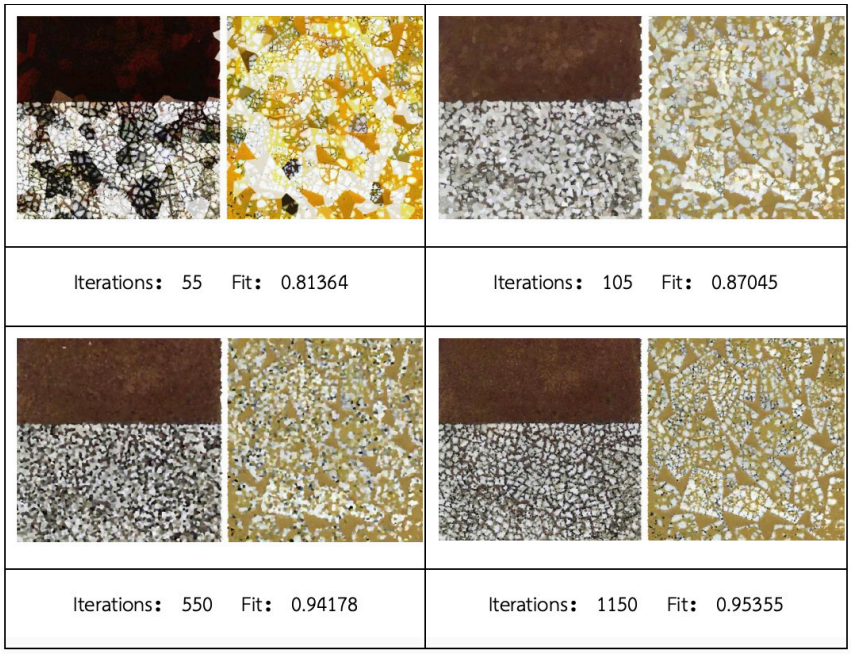
Source: Author, 2022

Firstly, the real coding genetic algorithm carries out binary coding of these patterns. With considering the number of patterns in the current pattern library, each pattern is encoded with 8 bits of binary number, and another 2 bits represent the direction and position of this pattern. In this way, the 30-bit binary coding string represents a decorative design scheme. In the compilation environment, population number 100, crossover probability 0.65, mutation probability 0.05, 0.6 in Fit function were selected, and satisfactory experimental results were generated after 100 iterations. Then the Model Fit is given by the designer through human-computer interaction, and the design engineer will automatically select from the pattern library. Finally, genetic operations such as single point crossing and basic bit variation are carried out to realize different combinations of the three types of patterns, so as to generate innovative pattern design of lacquer art and obtain satisfactory results for designers.

Table 1

The resulting lacquer decorative pattern

	
Iterations: 1 Fit : 0.73021	Iterations: 10 Fit : 0.79236



Source: Author, 2022

Test results (Table 1): From the number of iterations, the more iterations, the more delicate the effect will be, and the genetic data collected after accurate classification showed obvious high similarity. For example, iteration 550 and iteration 1,150 gene sequences are highly similar. The patterns show obvious differences after visualization. And the corresponding position features show obvious similarities. The similarity between the two output features is 82.98% after calculation. From the perspective of artistic effect, the best effect is between 50 and 100 iterations. The traditional pattern is free from the boundary of the original traditional pattern, retains the cultural connotation of the traditional pattern, and conforms to the modern aesthetic at the same time. The similarity between the two output features is only 39.23% after calculation, and the design parameter of the target evaluation is optimized. When the number of iterations is between 1 and 50, the difference cannot be easily discerned. Color sensitivity is affected by genetic genes. Fine resolution is a very important factor in decoration. Deviation is not conducive to the public aesthetic feeling of lacquer art works, and it is not conducive to large vertical expansion.

5.6 The Results and Benefits of Genetic Algorithm Applied to Lacquer ware Design

In the design and development process of lacquer decoration, the research can bring the use of genetic algorithm and the convenience of computer to collect various historical image data and decorative art effects of traditional classical lacquer art as the feature data set.

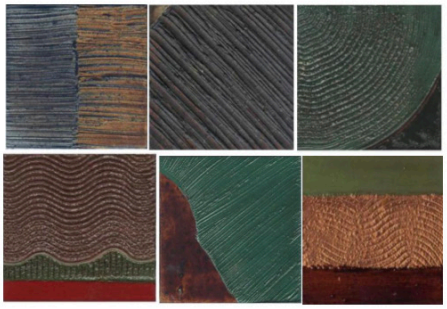
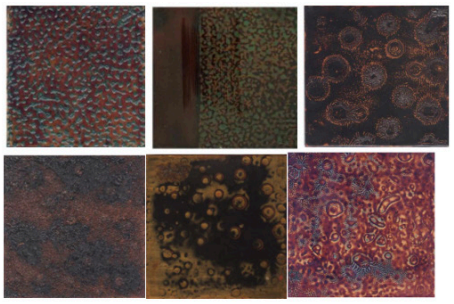
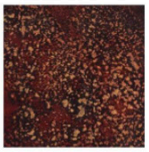
In order to ensure the balance of data, the experimental data is based on similar techniques of lacquer art. The same technique is collected in accordance with the classification management principle without artistic effect, 30 pictures of each, a total of 90 pictures. 20% of the images were randomly selected for genetic algorithm

testing, and the remaining 80% were used as training data. The size of the input decorative pattern image was enhanced by inverting the input image, and the influence of the background image was eliminated using the image processing software Photoshop. The resolution accuracy of the test image is more significant than 93.56%. During the calculation process, the images are grouped into inputs in a random order, ensuring the information's fairness in the training process. The gene pool and the objective function are specified in the module to achieve the optimal configuration of the objective parameters in an infinite step of evolution-hybridization-selection.

Test results (Table 2): The combination of the genetic algorithm and lacquer decorative patterns quickly generate a large number of lacquer pattern variants according to the 3 categories as embossing technique, debossing technique, and smoothing techniques. It accurately feeds back to the designers for feature extraction through iterative computation of the standard feature data to achieve the combination of pattern elements. The most matching scheme is selected among multiple schemes, and the preferred designed pattern is applied in the lacquer ware tea set. It fully increases the pattern's visibility and shows the lacquer ware pattern's decorative beauty, thus realizing the refinement of the cultural gene.

Table 2

Lacquer Patterns Genetically Calculated Applications

Category	Pattern selection process	Extraction results	Application in design
Embossing technique			
Debossing technique			

Source: Author, 2022

6. DISCUSSION

Genetic algorithms are utilized to specify genes and objective functions in the module to avoid the one-sidedness of subjective evaluation. The optimal objective can be achieved in infinite steps of evolution, hybridization and selection, and the optimal design can be screened out among the thousands of feasible solutions generated. The experimental results found that the lacquer pattern iteration of the raised class technique works best between 80 and 100 times, the concave class technique works best between 50 and 70 times, and the flat class technique works best between 70 and 80 times. The algorithm provides an optimal solution for eggshell pattern design by operating on the parameters of the eggshell technique. Each iteration of the algorithm retains the better individuals through selection and genetic operations and introduces mutation operations to increase the diversity of eggshell techniques. By using the genetically calculated pattern effects for editing, designers can make the pattern design process more accurately controlled and save a lot of time and cost.

Genetic algorithms provide designers with an efficient design environment that generates shape, color, texture, and diverse texture variants. The results of the algorithm help the designer to generalize the design features on the tattoo and feedback the data objectively. It can effectively solve the problem of the manual inability to quickly carry out the tattoo design, and realizes the extraction of decorative cultural genes. For example, the foam craft pattern in Figure 5 is the results from 88 iterations of the genetic algorithm calculation. At the end of the calculation, the maximum value of the current target evaluation and the corresponding design parameters are available. Lacquer designers objectively control the decorative aesthetics of the product and control the fusion and balance of traditional genes and modern genes so that the lacquer designers accurately control the decorative aesthetics of the product. The work embodies the traditional lacquer flow process and also meets the current aesthetic characteristics, especially with the public aesthetic demand. Using the powerful computing ability, the optimal design scheme is filtered out of the thousands of feasible schemes generated, which saves designers a lot of debugging and modification time. It makes easier to obtain customer satisfaction, designs more personalized lacquer works. It provides a new art form for simulating creative thinking.

Figure 5

The Application of Foam Technology in Lacquerware

Source: Author, 2021

Digital technology for the expression of lacquer culture should understand the connotation of 8,000 years of lacquer history, not too simple to carry out the iteration of decorative patterns. Genetic algorithms need to creatively extend the classic patterns of traditional lacquer art, collect typical patterns of various techniques, and highlight the cultural connotations embodied in lacquer art products. The patterns should reflect the innovative aesthetic concepts in order to let the public absorb the unique artistic temperament of the products. Utilizing the convenience of digitization to construct the pattern database of lacquer art, showing the unique artistic charm. It helps to promote the artistic charm of traditional lacquer art greatly. Internationally, Miki Asai is dedicated to creating lacquer jewellery that captures and preserves the beauty of the moment, in order to possess a slice of the fleeting world (Figure 6).

Figure 6

Miki Asai (Japan) Lacquer Art Innovative Works

Source: https://scottish-gallery.co.uk/product/pins-i-iii-and-ii, 2022

Moreover, the algorithm can be incorporated into digital design tools used by both small-scale artisans and larger manufacturers. For artisans, the technology can be integrated into software that supports creative freedom while improving efficiency. For manufacturers, the algorithm could be embedded in CAD systems or other production software, enabling seamless integration into existing workflows. Long-term, this could lead to increased productivity, the ability to mass-produce intricate designs, and cost savings on labor and material wastage. Artisans, designers, and manufacturers alike will benefit from improved precision, reduced production timelines, and the ability to personalize lacquer products at scale.

Genetic algorithms could also inspire new genres of digital art and experimental design, pushing the boundaries of how we define creativity. As the algorithms evolve, they can generate patterns and aesthetic forms that transcend human imagination, offering artists a collaborative tool that both complements and expands their creative abilities. This could ultimately contribute to the development of hybrid art forms that fuse cultural heritage with cutting-edge technology.

7. ORIGINALITY AND BODY OF KNOWLEDGE

Using computerized genetic algorithm technology and MATLAB's computational capabilities to simulate traditional lacquer patterns, this study combines traditional painting techniques with modern computing tools. Through repeated iterations, the most effective design configurations are evolved, providing an innovative method for the preservation and advancement of traditional lacquer art. This approach improves the efficiency of product design, enhances the overall aesthetic of the patterns, and enriches the application of digital technology in the field of cultural heritage.

8. RESEARCH RECOMMENDATIONS

8.1 Significance of Research

1) Combining computerized genetic algorithm technology with traditional lacquer pattern design provides a novel and efficient method. The study results highlight the practical significance of applying computer genetic algorithm technology in traditional lacquer pattern design. The incorporation of this advanced technology not only improves the design efficiency and enhances the overall aesthetics of the pattern.

2) The digital technology genetic algorithm respects traditional patterns' characteristics and incorporates the modern aesthetics, resulting in personalized lacquer works catering to consumer groups' preferences. The successful application of this technology paves the way for the future development of traditional lacquer art and may inspire similar research in other traditional art forms.

8.2 Suggestions for Future Research

1) Digitalization has laid a solid foundation for lacquer designers to improve their design efficiency, and the proposed methodology has great potential for application in traditional lacquer art. The next step in the design process may emphasizes the modern aesthetic orientation, which meets the personalized needs of consumers while preserving the essence of traditional patterns. The attraction to the consumer will take more enhancement so that its aesthetic value is positively recognized.

2) The application of computerized genetic algorithm technology has successfully automated the pattern generation process. Adding more novel genetic algorithm programs will be enabled to improve the innovativeness of pattern generation. Valuable resources for lacquer designers can be provided by establishing an online database.

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